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ABSTRACT

Interdisciplinary study with computer-based multimedia in the classroom is reviewed. The multimedia revolution involves multiple technologies and multiple modes of sensation, but the computer is at the heart of this revolution. Despite the many challenges, interest is strong for multimedia courseware. The predicted market is enormous, and nowhere more so than in science education. Interactive multimedia is ideal for science instruction. A case study of multimedia use in middle school earth and life science classes by a teacher with no previous computer experience illustrates how conventional instruction can be enhanced. An overall increase in visual literacy must accompany scientific literacy. The requirements for visual literacy are being explored by a number of researchers, and guidelines are being formulated for the design and evaluation of multimedia products. The Santa Fe Christian School (New Mexico) is an example of building visual and scientific literacy in the planned use of multimedia to help students assess their abilities to work in various styles. (Contains 17 references.) (SLD)

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Interdisciplinary Study with Computer-Based Multimedia

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The science educator has some new tools at his disposal. There is a unique opportunity to increase visual literacy in education as well as for curriculum reform. Yet more than newfangled equipment is necessary to accomplish better education. Aspects of visual literacy as well as Guilford's Structure of Intellect (SOI) model give us important considerations for instructional design which teaches facts and inspires students in compelling ways. Thus, a number of conceptual tools are presented for designing courseware for the interactive multimedia platform which is reviewed.

THE MULTIMEDIA REVOLUTION

Components

The multimedia revolution involves multiple industries, multiple technologies, and multiple modes of sensation. Telecommunications brings information from a distance to the learner on a television set or the desktop. Distance learning brings expert instruction via video and audio in real time. Also, telephone, digital voice mail, and computer BBS allow further methods for communication in any educational process. For example, the University of Phoenix offers an MBA which requires absolutely no on-campus activities.

At the heart of the multimedia revolution is the computer. Dramatic improvements in speed, capacity, compression, and price have allowed ordinary people to own machines with incredibly improved functional abilities relative to a short time ago. With more capable digital processing, temporal files are now possible, i.e. audio and video information of increasing fidelity can reside in computer memory. Finally, the laser printer and desktop publishing have revolutionized the cost and quality of print materials. From short memos to full manuscripts, publishing has become affordable at the grassroots level.

Gutenberg's Gamble

With all the exciting developments in multimedia one must remember to take an historical perspective on the application of educational technology. The revo-

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lution is of Gutenbergian proportions, but the risk for temporary failures is also as great as that experienced by Gutenberg himself (Gilardi, 1992).

A better jeweler and font engraver than marketeer, history's technological Columbus sailed into an economic morass. Because he misjudged the information-processing preferences of his market, Gutenberg actually saw his investment in the new printing lead him into dire financial bankruptcy. The Gutenberg Bible contained only one-tenth of the official manuscript available from the church. He published on parchment, requiring the slaughter of 40 sheep per book rather than on the new pulped rags material. Thus his books were approximately $25,000 per copy rather than one or two thousand dollars for the monks' handwritten works. Furthermore, he did not include the usual level of fine artistic embellishment:

> The protopublisher's third mistake: his 'automatic bible' contained no illustration--not even decorative initial letters which were left unembellished or even blank. Without 'illumination' a quality book was considered incomplete; therefore, in order to achieve the final product, the client incurred a considerable extra expense.
> (Gilardi, 1992, p. 7)

Contemporary multimedia publishers face a similar tradeoff. They must balance cost of development against expectation of customer. The high standard of commercial television is demanded by the eye, yet the affordability of a book is required by the pocketbook. Falling short of these benchmarks in the educational marketplace can mean a shortlived product.

Persistent Trends

Despite these challenges, interest remains strong for multimedia courseware. In the business world a recent study by Answers Research found that the use of multimedia involves 36% for use in training, 45% for off-site presentations, and 61% for on-site presentations (Borzo, 1992). Government analysts estimate the use of multimedia to grow from $900 million in 1992 to $2.4 billion in 1995 (Zurier and Liebowitz, 1992). The research record of interactive multimedia in training is a good one. A recent study by Fletcher (1990) reported a metaanalysis of studies in the military, industrial and educational spheres. This review found the educational technology to be effective and cost-effective. Still holding true is the 30, 30, 30 finding: one-third more learning, one-third less time, one-third less cost. O'Connor (1992) reported that a recent LINK study predicted that multimedia revenues from business, consumer, and education will grow from $777 million in 1991 to $13 billion by 1996.

In education the predicted growth in multimedia hardware and software is clear. The 1991-92 Market Study Report by Software Publishers Association (1992) dis-

covered that sales for videodisc and CD-ROM are both predicted to have strong growth in the near-term. By 1991 there were 94,400 CD-ROM's installed in the schools. Another 64,600 CD-ROM's will be purchased by the end of the 91-92 school year. The number of videodisc players installed and planned for FY 91/92 are 110,600 and 60,900, respectively. Thirdly, integrated learning systems account for another major portion of expenditure on multimedia. It was estimated that 10% of all schools have ILS. The average number of stations at a school is 22.6 at a cost of $18,200 per station.

In FY 90/91 the schools spent a total of 598 million dollars on personal computer software. Two-thirds of purchases in the secondary schools and 87% of elementary were for instructional software. It was also interesting to note that in the software buying decisions in this survey, the most important factors related clearly to visual literacy and one of the key aspects of Guilford's Structure of Intellect model (SPA, 1992). They included:

1. Software that is easy to use;
2. Software that has a graphical user interface; and,
3. Software that builds problem solving skills.

MULTIMEDIA IN SCIENCE EDUCATION

Explosion in the Lab

Science education is the area of the most dramatic and intense work with educational technology. As Eiser (1992) points out, in the last 18 months more than a dozen major interactive videodisc packages for science instruction have been produced and marketed. The need for scientific literacy and the great improvements in speed, capacity and resolution of visual archives have combined to make an explosion of curriculum development.

Interactive multimedia is ideal for science instruction. Simulation of dangerous or expensive lab experiments can be observed over and over again without risk to limb or budget. Exploratory games involving academic concepts and facts facilitate scientific literacy. There is opportunity to ensure ability to solve problems as well as memorize facts. Dynamic and micoroscopic events can be blown up for all to see and stepped through in slow motion. With color, motion, stills, and the access power of a computer, multimedia is apt to be a helpful tool for any science teacher.

A Science Project

In the summer of 1990 the Santa Fe Christian School received a $50,000 grant from the Ahmanson Foundation to implement an interactive multimedia workstation for instruction in Middle School Earth and Life science (Couch and Peterson, 1991). The teacher, while expert in the content and pedagogy of her field, had never used a computer in her professional or personal life. Thus, she was an ideal test case for the "teacher-friendliness" critierion of good educational technology.

The courseware employed was videodisc packages from Optical Data Corporation and Videodiscovery. Content from these products was used in a generic sense, with the teacher adding distinctive material from her experience and Christian philosophical perspective. The supplementation was facilitated by an intuitive GUI-type "Presenter Stack" designed by Matt Evans in the MMCDL. The material was developed and presented on a large-screen television with a laser videodisc player and a Macintosh IIci computer.

Any instructional design will fall somewhere on a rationalist-romanticist spectrum. That is, some teaching will tend to focus on the facts of the discipline and other teaching will focus on the feelings of the student. Our goal is to remember both the objective and subjective aspects of education. Indeed, a Christian epistemology provides a foundation for considering the objective nature of the world as well as the heart. Working with the multimedia courseware, the teacher found that she became increasingly metaphorical and illustrative in her teaching. Whereas before she had to be very careful to not teach "over their heads", the convenient visuals allowed communication to be easier and richer. At the same time the rationalist component was strengthened because she used the computer to prepare expository outlines for the students. Based on observation, interviews and questionnaires, the students and teacher's experience with a rich reservoir of visual images and sequences gave them an enhanced scientific literacy and motivation for further study.

VISUAL LITERACY

Constructivist Definitions

In addition to scientific literacy, an overall increase in visual literacy occurred. Sinatra defines visual literacy as "the active reconstruction of past visual experience with incoming visual messages to obtain meaning." (p. 5, 1986).

In Kuhn's discussion of scientific paradigms, he emphasizes that a discipline is more than its facts and explicit theories. Paradigms are also images of scientists executing their methodologies as well as the visual metaphors that guide theoretical thinking. The famous "thought experiments", such as Einstein's man riding on a train through space and models such as the picture of DNA developed by Watson and Crick are based in the visual dimension. While the verbal and symbolic languages are used in science, it is often the visual language that stimulates discovery and helps communication of the scientific facts.

The "Who" of Visual Literacy

As the instructional designer prepares courseware with a visual emphasis, it is best done with principles consistent with the constructivist definition given above. A constructivist view of the multimedia learner and his sociological position is found in Omar K. Moore's Clarifying Environments Program (1969, 1980, 1992).

Moore's theory for instructional design is synaesthetic and is

particulary helpful for those who want to promote visual literacy in education. He proposes four principles for understanding the learner as he works with instructional visual material:

1. Perspectives (Is the learner in the role of an agent, a patient, a reciprocator, and/or a referee?)
2. Productivity (Is the learner able to use the material in a heuristic way in future situations?)
3. Personalization (Is the learner working in a self-paced, exploratory, discovery-oriented, interconnected way with immediate feedback?)
4. Autotelicity (Is the learner working voluntarily?)

The "How" of Visually Literacy

The cognitive science of computer interface has been nicely articulated by Donald Norman of U.C. San Diego in his book *The Psychology of Everyday Things*. (1988) Considering the appearance of various machines, especially electronics, Norman has given theoretical and practical analysis of the intuitive nature of how things work. He describes the ergonomic feedback loop in terms of two basic phases: Execution and Evaluation. Applied visual literacy can be conceptualized in a similar way: an active reconstruction which involves executing and evaluating actions with visual material.

Norman presents an "approximate model" of how people interact with the visual cues of a computer interface. Seven imprecise stages are as follows:

- Forming the goal
- Forming the intention
- Specifying an action
- Executing the action
- Perceiving the state of the world
- Interpreting the state of the world
- Evaluating the outcome

Verbum Interactive 1.0

Prototypical examples of reconstructive multimedia science education can be found in *Verbum Interactive, 1.0*, the first CD-ROM multimedia magazine in which work from the SFEF MMCDL appears. In both the Zoo Adventure and Space Directory with Michael Carrol, the user is making choices and gathering information in a rich verbo-visual environment.

In their *Windows on Science* manual (1991), the signs of visual literacy are listed as follows:

1. Grasp composition of images
2. Decode meaning of images
3. Infer from image
4. Disregard emotional interference during critical analysis
5. Manipulate image mentally
6. Translate visual data into verbal insight
7. Incorporate new visual information into existing core of knowledge
8. Communicate through showing, arranging and composing visual images

As these activities are done, the who and how guidelines can be used for design and evaluation of multimedia products.

STRUCTURE OF INTELLECT

The "what" of Visual Literacy

In the late 1940's a research psychologist named J. P. Guilford developed a factorial approach to the structure of intellectual abilities. Throughout his research he stipulated a three dimensional cube of intellectual abilities which can be assessed and trained (Guilford, 1966). In addition to the Semantic and Symbolic dimensions the third main component of this schema is a dimension known as the Figural which primarily includes the visual abilities.

Like the Semantic and the Symbolic, the Figural content can be approached in various ways, at varying levels of complexity. Operations include Cognition, Memory, Evaluation, Problem Solving, and Creativity. These abilities are employed with material that ranges across Units, Classes, Relations, Systems, Transformations, and Implications.

A Research Center

In the 1992-93 academic year Santa Fe Educational Foundation and Key Technologies International plan to develop a Research Center on the campus of Santa Fe Christian School. Students will participate in SOI assessment of their abilities to work in various styles. Testing and training for weak areas will be delivered via computer through Online SOI and SmartMods. Teachers will alter their teaching and use of media as they learn about the individual students and reflect on the SOI three-dimensional grid of pedagogical considerations.

Multimedia affords the clear opportunity to build visual and scientific literacy through instructional design that takes into account the who, how and what of a student's visual experience in science education. As teachers and students become more adept in the visual realm, they may be able to balance the rationalist and the romantic poles of curriculum development.

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